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1a. RE
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2a. SECURITY CLASSIFICATION AUTH

3. DISTRIBUTION/AVAILABILITY OF REPORT
APPROVED FOR PUBLIC RELEASE
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2b. DECLASSIFICATION/DOWNGRADI CHEDULE

4. PERFORMING ORGANIZATION REP NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)
AFOSR-TR- 90-0374

6a. NAME OF PERFORMING ORGANIZATION	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
Pennsylvania State University		AFOSR/NA

6c. ADDRESS (City, State, and ZIP Code)	7b. ADDRESS (City, State, and ZIP Code)
Department of Mechanical Engineering University Park, PA 16802	Building 410 Bolling AFB, DC 20332-6448

8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
AFOSR	NA	AFOSR-89-0139

8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
Building 410 Bolling AFB, DC 20332-6448	61102F	2307	A2	

11. TITLE (Include Security Classification)
Development of a Postprocessing and 3D Graphical Imaging Facility (Unclassified)

12. PERSONAL AUTHOR(S)
Brasseur, James G.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Technical	FROM 12/1/88 TO 11/30/89	1990, January 31	5

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Graphical Imaging, Scientific Visualization, Turbulence

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION	
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL JAMES M. McMICHAEL	22b. TELEPHONE (Include Area Code) 202-767-4936	22c. OFFICE SYMBOL AFOSR/NA

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE

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Final Technical Report
DURIP Award AFOSR-89-0139
January 31, 1990

DEVELOPMENT OF A POSTPROCESSING and 3D GRAPHICAL IMAGING FACILITY

James G. Brasseur
Department of Mechanical Engineering
Pennsylvania State University

ABSTRACT

This grant supported the acquisition of equipment towards the development of what has been termed a "Postprocessing and 3D Graphical Imaging Facility". The primary function of the facility is in the *analysis* of numerical and experimental data, perhaps created in other laboratories, through the combination of quantitative and graphical tools. Specifically, the motivation is the analysis of Full Numerical Simulations of turbulent flows to study time-dependent three-dimensional structural characteristics and the interrelationships among turbulent structures in different fluctuating variables. The hardware purchases towards these ends includes two Stardent Titan graphics 'mini-super-computers', one with 32 Mb memory and a single CPU, and the other with 64 Mb memory and two CPU's, both fully loaded with enhanced graphics, Fortran and C compilers and other software, nearly 3 Gb hard disk storage, a thermal color printer, a laser printer, and an X-terminal. The facility is fully networked as an Internet node. Some College matching funds remain. These will be combined with other funding sources to purchase hardware and software for the recording of animated sequences on video tape.

1. OBJECTIVES

The use of powerful computers is now an integral part of both numerical and experimental analysis. Some of the largest, and most time-consuming calculations are carried out in the study of fluid flows—in particular, turbulent flows. For example, the largest turbulence calculations currently involve over *10 million* nodes, with perhaps 20-30 (or more) variables of interest at each node, over perhaps 100 (or more) time steps. This is an enormous amount of data. Experimentally, the same trend in data-collection may be found; 3D particle-tracing methods are on the verge of generating data-sets every bit as large and complex as those currently being generated numerically. An important use for these data is in the study of three-dimensional structural elements in the flow. The topology of the structures embedded within the data-sets is extremely complex and highly time-dependent. The graphical and computational tools currently available to intelligently extract structural information are crude at best, or simply not available. Although much press is given to the need for larger computers for the *production* of data, the *analysis* of the data is rapidly becoming a major bottleneck in many fields of science.

The objectives of this program are towards the development a facility dedicated to the type of analysis alluded to above. The key element is analysis of large data-sets through *concurrent interaction* between (1) the human user, (2) the graphical display (for identification and manipulation of graphical objects), (3) applications designed to quantify topological and other characteristics of graphical objects, (4) data-sets of several physical variables stored on disk, and (5) specific applications which link the different data sets with the graphical display for quantitative analysis. The underlying theme is the formation of a symbiotic relationship among human intelligence, computational power, and high-level graphical imaging in data analysis—an interactive fusion of human and machine 'intelligence,' if you will.

With support from this grant, together with considerable matching from Pennsylvania State University, most of the hardware for the facility has been purchased. What is left to do, however,

is the hard part—the development of the software applications and interfaces required to turn the hardware into the versatile facility envisioned above. With support from a recent U.R.I./AFOSR award, we will begin development of a modular set of graphical-computational tools which can be interconnected in a variety of different ways. Some of these modules would be for subjective observation of graphical images, and manipulation of the graphical objects in a variety of interesting ways. Other modules would use information generated in the formation of the graphical images to quantify the topology of and topological relationships among different graphical objects. Another set of modules would be designed for interactive quantitative analysis of data sets stored on disk by combining access to these data with direct interaction between the user and the graphical images on the screen. Finally, a set of higher-level modules would allow the user to combine lower-level modules in different useful ways. All of these modules will likely be incorporated into a new graphical sub-system developed by Stellar computers, and soon to be available on the Titan†, called 'AVS'.

2. Status of the Facility Hardware

The total DURIP Equipment Grant award was $216,373 to which AFOSR contributed $71,393. The balance is matching funds from Pennsylvania State University, the College of Engineering, and the Department of Mechanical Engineering. The following items have been purchased:

- Ardent Titan Computer (Unit A), which includes
  2 processors, 64 Mb memory, three 380 Mb disk drives,
  enhanced graphics, software (compilers, UNIX, NFS, TCP/IP, etc) $101,705.00
- Ardent Titan Computer (Unit B), which includes
  1 processor, 32 Mb memory, three 760 Mb disk drives,
  enhanced graphics, software (compilers, UNIX, NFS, TCP/IP, etc.)
  knob box $91,020.00
- QMS PS810 Laser Printer $3,681.73
- Centronix Cable for QMS Laser Printer $35.00
- Tektronix 4693 DX Color Thermal Printer $7,445.00
- Mac II Ethernet Card $294.00
- Visual Technologies 19" X-terminal $2048.90

total to date: $206,303.68

The hardware components of the complete Postprocessing and 3D Graphical Imaging Facility are shown in Figure 1. Left to purchase from matching funds is the animation arm of the facility, and if money allows, a Mac workstation. An optical disk unit was not included in the original DURIP proposal, however this item will be purchased with funds from a recently awarded U.R.I. grant from AFOSR.

It will not be possible to purchase the complete video arm with the remaining $10,069 from the DURIP grant. For this reason, careful deliberations for the use of this money are still under way. The hope is that by combining the remaining funds from this grant with with funds from other grants, and by combining resources with Dr. Philip Morris of Aerospace Engineering for shared use of some of the video equipment, all items in figure 1 will eventually become part of the facility. The many details remaining are currently under study.

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† Last year Ardent and Stellar Computers merged to form a composite company called "Stardent Computers." As a result of the merger, the AVS graphical system developed by Stellar for their 'GS' machine is being ported to the Titan. We are a beta test site for the port; the beta version will be available in mid-March.

3. USE OF THE POSTPROCESSING AND 3D GRAPHICAL IMAGING FACILITY

The facility is being used by the following investigators for the indicated projects:

Professor James Brasseur

- *Structure and Dynamics of Turbulent Flows.*
  Support: AFOSR and U.R.I./AFOSR programs.
  Personnel:
  Dr. P.K. Yeung, Research Associate since 12/89.
  Wen-quei Lin, Ph.D. Candidate, since 8/88.
  Qunzhen Wang, Ph.D. Graduate Student, since 8/89.
  Brian Moquin, Graduate Student, since 1/90.
  Chao-hsuan Wei, Graduate Student (currently unsupported)
- *Modeling the Human Swallowing Process*
  Support: NIH
  Personnel:
  Dr. Meijing Li, Visiting Research Associate, since 11/88.
  Mukund Dusey, Ph.D. Graduate Student, since 6/89.
  Pei-ying Hsieh, Ph.D.Graduate Student, since 8/89.

Professor Charles Merkle

- *CFD Analysis of Rocket Combustion Flowfield*
  Support: NASA-Lewis
  Personnel:
  Jonathan Weiss, Ph.D. Candidate, since 8/88.
- *CFD Modeling of Microwave Propulsion*
  Support: AFOSR
  Personnel:
  Sankaran Venkateswaran, Ph.D. Graduate Student, since 8/88.
- *Diffusion Flames in Unsteady Jets*
  Support: Gas Research Institute of Pennsylvania
  Personnel:
  Ashvin Hosangadi, Ph.D. Graduate Student, since 8/88.

Professor Laura Pauley

- *Numerical Study of Unsteady Boundary Layer Separation*
  Support: ONR
  Personnel:
  Muti Jeng-Chyan Lin, Ph.D. Candidate, since
  Matthew Ripley, M.S. Graduate Student
- *Stability of Laminar Boundary Layers in Rocket Nozzles*
  Support: NASA Center, Pennsylvania State University
  Personnel:
  Samir Dagher, M.S. Graduate Student, since 1/90.

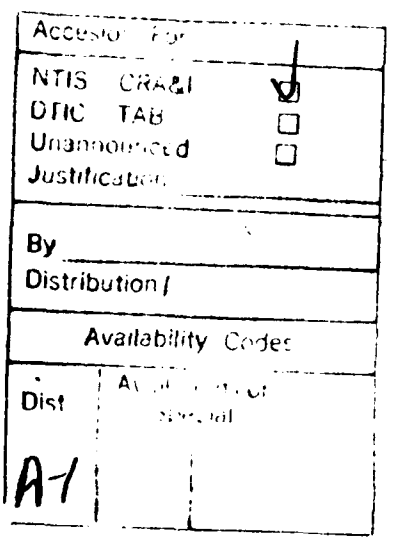
STATUS OF THE FACILITY DEVELOPMENT

With the exception of the video equipment, most of the hardware is in place. To turn this hardware into the facility described above will require a great deal of software development, both graphical as well as analytical. Clearly, the development of applications for analysis must be carried out in concert with the study of fluid flows which draw on these applications. With the recent award of a 3-year U.R.I. grant in collaboration with experimentalists at Yale University (Professor K.R. Sreenivasan) and Princeton University (Professor A.J. Smits), personnel have been added to the group to make these developments possible. In particular, we have added an Electrical Engineering student to the group, Brian Moquin, whose efforts are dedicated entirely to Graphical Imaging and Scientific Visualization. Brian will work together with the other researchers in the group towards the development of modules for graphical and quantitative analysis, and the development of interfaces for combination, automation, and interactive use of the modules in the analysis of scientific data.

The development of high-level graphical software is a time-consuming task that will require a great deal of effort over an extended period of time. Even with the current personnel in the turbulence group, it will not be possible to move at the rapid pace desired in the development of the Postprocessing and 3D Graphical Imaging Facility. Consideration is therefore being given to the possible submission of a grant application to NSF specifically towards this goal.

PAPERS, MEETINGS, ETC.

As an equipment grant, the issue of papers and meetings is somewhat irrelevant, with the exception of a discussion which was presented by J. Brasseur in February 1989 at NASA-Langley on the establishment of the Postprocessing and 3D Graphical Imaging Facility at Pennsylvania State University. Research which has been carried out using the facility has recently been presented at APS, Division of Fluid Dynamics Meeting, Palo Alto, CA.



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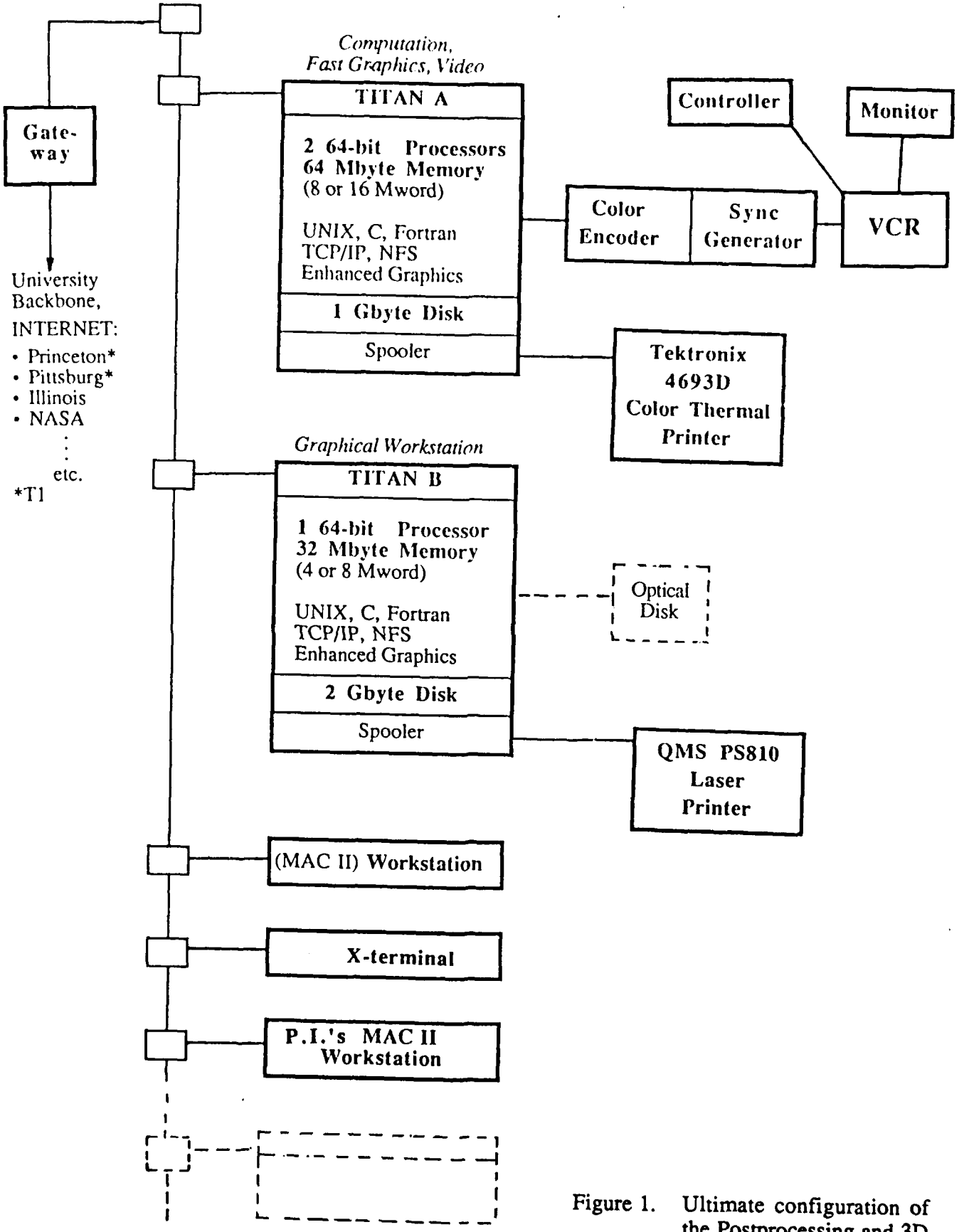

Figure 1. Ultimate configuration of the Postprocessing and 3D Graphical Imaging Facility